METHOD OF DRILLING OIL WELLS

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Filed: Feb. 23, 1971

Appl. No.: 117,966

Related U.S. Application Data
Continuation-in-part of Ser. No. 821,272, May 2, 1969, abandoned.

U.S. Cl. 175/65, 175/72, 166/305
Int. Cl. E21b 21/04
Field of Search 175/65, 66, 72; 166/283, 305 R; 252/8.5 B

References Cited
UNITED STATES PATENTS
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2,073,413 3/1937 Cross et al. 252/8.5 B
2,887,301 5/1959 Day 175/355 X
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3,319,715 5/1967 Park 166/283
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A combination drilling and stimulation process for drilling oil wells and especially those through oil sand which contain a great deal of intergranular clay, which makes use of a clear solution containing calcium chloride instead of the usual drilling mud. The solution of calcium chloride is treated with a liquefied surfactant, and the mixture is forced down the annulus formed between the drill pipe and drill collars, and the wall of the drill hole. At the bottom of the well the solution passes the cutting face of the bit and picks up the chips, flushing them outwardly through the drill collars and drill pipe and out at the top.

8 Claims, 4 Drawing Figures
METHOD OF DRILLING OIL WELLS

This is a continuation-in-part of copending application Ser. No. 821,272, filed May 2, 1969, now abandoned.

The most common method of drilling oil wells is one known as the hydraulic rotary drilling method. This method consists of rotating a cutting bit, comprising individual cone bits, which is attached at the bottom of a hollow drill string of pipe and drill collars to progressively chip away the layers of earth. To force the chips of rock and earth formation to the surface, the common practice has been to force a fluid known as "drilling mud" or "drilling fluid" down the hollow drill string, thence outwardly between the cutting teeth to clear the teeth of accumulated dirt, and thence out into the annulus formed between the wall of the well which is being drilled and the exterior of the drill string. The mud picks up the chips of rock and earth and carries them with it to the surface, in this way to clear the well as it is drilled, in a progressively deeper. Mud, as it is called, has a number of advantages or consequence when used for this purpose. It has a high viscosity and high density which makes it capable of carrying the cuttings from the rotating cutting bit up the annulus to the surface at a relatively low velocity, that is to say, about 125 to 150 feet per minute. Should mud circulation be temporarily stopped, the settling velocity of cuttings is reduced. By reason of its high density, the mud tends to buoy up the drill string thereby to reduce the strain on the drill rig, and mud in the annulus is at a high hydrostatic pressure which is exerted outwardly against the wall of the well and this helps prevent cave-ins and blow-outs which might occur as the result of high formation pressure. Additionally, finely divided solids suspended in the drilling mud work to build a filter cake on the wall of the well, frequently termed a bore hole, thus reducing loss of mud which might otherwise filter to the formation. The mud also serves to lubricate the bore hole wall. A further attribute of mud is that of lubricating the bearings of the cone bits, and keeping them relatively cool. The mud further serves as a medium through which various types of logs are run to determine characteristics of the formations which have been penetrated as the drilling progresses.

Prior art is exemplified by the following patents: Loomis et al. U.S. Pat. No. 1,819,646; Cross et al. U.S. Pat. No. 2,073,413; Day U.S. Pat. No. 2,887,301; Parks U.S. Pat. No. 3,319,715; and Moore U.S. Pat. No. 3,070,179. At the present time oil well stimulation processes are conducted after the drilling process has been completed and, as such, constitute a separate and distinct operation.

The foregoing comments are made with respect to existing drilling techniques in order to point up the manner in which applicant's method departs from the conventional and in its departure causes some very significant changes in operation and results.

Further, and by way of example, there are in California two basic types of drilling muds. They are commonly identified one as the water base type and the other as the oil base type, the water base type the most commonly used. Water base mud consists basically of a bentonitic clay in fresh water suspension. Various additives are often employed, the most common of which is the mineral barite in the form of barium sulphate in a finely divided state. This is added to the mud in considerable quantities to increase the specific gravity or weight of the mud. Oil, usually Diesel oil with an emulsifier, is added to the mud to improve its property of lubricating the bore hole wall.

Water base muds are, to a varying degree, thixotropic, which means that when movement in the well causes, namely, either movement of the drill or movement of the flow of mud, the mud tends to thicken or jell. In California most common water base mud has a weight of 80 pounds per cubic foot. This is appreciably heavier than fresh water which, to assist in drawing understandable comparisons, is 62 pounds per cubic foot. The mud described hereinabove is relatively inexpensive and is used in both exploratory and development drilling, except that it is common practice to change over to an oil base mud prior to drilling through the producing strata in development drilling.

Oil base mud is a name applied to inverted emulsion mud which consists of a water-in-oil emulsion. The emulsion may be described properly as tiny droplets of water suspended by use of an emulsifier in a continuous oil phase. The oil frequently chosen is diesel oil. The reason for selection of an oil base mud is that emulsions of high viscosity have a low filtrate loss and any filtration that does take place from the bore hole outwardly into the formation must come strictly from the oil phase of the mud, the water phase of the mud or emulsion droplets remaining in the bore hole. Should there be any oil phase filtration into an oil bearing formation, such filtration would be more compatible than would filtration into the formation by fresh water from a water base mud. This is especially true when the swelling of formation clay is taken into consideration, especially in the presence of fresh water. Some attempts to control the situation have included putting additives in the mud, which inhibit the swelling of formation clay and shale. Despite the advantages of oil base mud, it is not used as widely as the water base mud because of the cost being four to five times greater.

Despite the wide acceptance of mud type drilling techniques above described, unsolved problems are constantly a challenge, among which is inability to maintain good hole stability, to prevent loss of drilling fluid into the formation, to prevent damage to oil producing zones, and the control of formation pressure.

What is meant by maintaining hole stability is the preventing of shale and sand from sloughing into the bore hole of the well from the wall, after the drill has passed. This problem, primarily, is attributable to the tendency of clay, which is the main constituent of shale and a minor constituent of sand, to hydrate or take on water from the water base mud and start running. When shale does start hydrating and moving, the bore hole, the result is production of masses of clay, known as "gumbo," which can restrict the flow of mud through the annulus. When this happens, it will cause the drill string to stick and prevent logging tools being sent into the bore hole for their usual purpose of logging the well. The gumbo also tends to restrict mud laden with cuttings from the drilling operation to flow in the annulus, and causes formation abrasion and hole enlargement adjacent the restrictions thus formed.

Loss of large quantities of drilling mud to the formation can be expensive. Loss is primarily the result of
higher than desired bore hole pressure, namely, pressure in the annulus, which causes a breakdown of the formation. Hydration of clay in the formation because of the presence of water can increase the mud viscosity in the annulus and thereby lead to the building up of an elevated pressure in the annulus. Gumbo, produced as mentioned above, can restrict the flow of mud in the annulus to a degree such that pressure in the annulus at a location below the restriction becomes excessively high. Further still, there can be high pressure surges created when drill pipe is run into the mass of mud in the hole at a high rate of speed, and when rapidly initiating mud circulation. What has been described are circumstances which tend to increase bore hole pressures above normal values on which occasion there is an increased danger of formation breakdown with an accompanying loss of mud.

There are also occasions where damage can occur to the oil zones and reduce expected rates of production. A common cause of damage is hydration of the oil producing formations in the area immediately surrounding the bore hole. Hydration results in the swelling of intergranular clay in the oil sands where water base mud is being used. When the clay expands, it can plug up to a great extent the porosity of the formation and reduce the permeability or capacity of the oil sand to transmit the flow of crude oil into the well. Still another cause of damage in the use of conventional drilling mud is what is termed "mudding off" of the oil producing formations in the bore hole area. This results from the suspended solids, namely, finely divided bentonitic clay, weight material, clay from the formation, etc., in the drilling mud being forced into the intergranular pores of the oil sands or the fracture porosity of fractured shale reservoirs, thus reducing porosity and permeability. It should be borne in mind that a conventional 80 pound water base mud commonly contains about 10 percent solids by volume, and in contrast a conventional 80 pound oil base mud commonly contains solids to about 20 percent of its volume.

In the proper drilling of oil wells it is necessary to control what is termed formation pressure as much as possible. This means pressure in the formation into which the well is drilled and particularly pressure in the producing strata. Normally, this is controlled by the sheer weight of the column of mud, namely, hydrostatic pressure. As long as hydrostatic pressure exceeds formation pressure, no problem arises. On the other hand, if the formation pressure exceeds the hydrostatic pressure, fluids of the formation will push the drilling mud out of the hole, the fluids forcing their way to the surface, sometimes quite violently. This is commonly known as a "blow-out" and blow-outs are dangerous and expensive. A circumstance of this kind is commonly caused by the swabbing of the bore hole by thick mud or gumbo which has collected, the swabbing being done while the drill string is withdrawn. Hence, whether the mud is a water base mud or an oil base mud, if it is allowed to thicken beyond normal values, it can collect around the bit and create a swabbing effect. During the usual drilling phase filter cake tends to build up in the bore hole. In the applicant's method, the formation of filter cake is substantially minimized if not eliminated. Another often troublesome situation, however, frequently arises. Some appreciable pressure is required to circulate drilling muds while drilling is in process. Surges of pressure are frequent when running drill pipe in the well. When there is a relatively low formation pressure, the high pressures often drive mud into the formation, or cause formation breakdown which is often accompanied by the unnecessary loss of large amounts of drilling mud.

In certain California areas, for example, there exists what has been termed dirty oil sands, containing a great amount of intergranular clay, and such sands have relatively low porosities and permeabilities. These poor characteristics are the cause of relatively low rates of oil production which have rendered many dirty California oil sands noncommercial. This applies especially where the intergranular clay is sodium montmorillonite, which has a great affinity for water.

It is therefore among the objects of the invention to provide a new and improved combination drilling and stimulation process for the drilling of oil wells which overcomes or at least minimizes many of the objections encountered in the use of water base or oil base mud.

Another object of the invention is to provide a new combination drilling and stimulation process for the drilling of oil wells which involves substituting a chemical solution for the conventional water base and oil base muds which have heretofore been commonly in use.

Still another object of the invention is to provide a new and improved combination drilling and stimulation process for the drilling of oil wells which is capable of maintaining good hole stability, which avoids the problems of hydration of clay and shale forming the wall of the well, which minimizes restrictions, minimizes the loss of drilling fluid to the formation, minimizes formation damage, allows easier entry into the bore hole of wire-line equipment, minimizes blow-outs, and which is of such character that it will allow more conclusive evaluation for oil and gas content of the returned cuttings and drilling fluid.

With these and other objects in view, the invention consists in the arrangement and combination of the various parts of the method, whereby the objects contemplated are attained, as hereininafter set forth, pointed out in the appended claims and illustrated in the accompanying drawings.

In the drawings:

FIG. 1 is a schematic sectional view of a drilling operation.

FIG. 2 is an elevational view of the drill in a typical well.

FIG. 3 is a cross-sectional view on the line 3—3 of FIG. 2.

FIG. 4 is a fragmentary longitudinal sectional view of a special rotary drill head on line 4—4 of FIG. 2.

Drawing on a typical condition as an example in describing applicant's method, it can be assumed that the drilling operation will be one for drilling a 7/8 inch hole making use of a drill pipe 4½ inches in diameter. When, for example, the drilling fluid in the present instance is a solution containing calcium chloride among the multiple ingredients, it is circulated down the annulus formed between the exterior of the drill string and the wall of the drilled well at a rate of 150 feet per minute. The relative volumes are such that under this circumstance, when drilling fluid is forced past the
3,692,125

cutting face of the bit into the bottom of the passage through the drill string, the rate of passage of fluid upwardly will be about 450 feet per minute. It should be borne in mind in connection with this description that the method described by applicant is essentially a method wherein the flows are reversed from conventional practice.

Applicant's method employs a specially prepared clear water solution of calcium chloride and a surfactant, the solution having a weight of 80 pounds per cubic foot. This is about the weight of a conventional drilling mud and correspondingly heavier than water. There are, however, circumstances which may suggest varying the weight of the solution to one as low as 65 pounds per cubic foot to one by addition of other chemicals, as high as 120 pounds per cubic foot. An 80 pound solution of calcium chloride has an A.P.I. funnel viscosity of about 32 seconds per 1,000 cubic centimeters, which is a great deal lower than that of most drilling muds. Some oil base muds have viscosities of 90 to 100 seconds.

In using the reverse circulation technique certain changes in conventional cone bits are needed. The changes require a drilling head which deflects by means of steel skirts the flow of calcium chloride solution inwardly past locations where teeth of the bit impinge upon the formation, thence upwardly through locations where teeth of adjacent cones mesh, thence upwardly through a central passage, and then upwardly through the drill string.

In an embodiment of the invention chosen for purposes of illustration, there is shown a well 10 which has already been started into the earth drilled in the conventional manner and lined with casing 11 as is the common practice through the formation 12. The bottom portion of the well is then drilled and stimulated simultaneously, by use of the applicant's method through the producing formation, or strata 13, and partly into the formation 14 where at the depth to which it has progressed there is a bottom 15. The drilling is accomplished by employment of a bit or drill head indicated generally by the reference character 16 which is attached to the drill string 17 made of conventional lengths of drill pipe and drill collars. At the lower end of the drill head is a series of cutting cones 20, 21 and 22 mounted so as to rotate upon conventional bearings with the teeth 26 on adjacent cutting cones meshing with each other. A central passage 27 runs entirely through the drill head 16 and opens above the cutting cones. Skirts 29, 30, 31 between legs 32, 33, and 34 of the drill head 16 serve to expose only the very lower end of the cutting head 16, namely, the portions of the cutting cones which are located below the legs of the drill head, and the portions in the area of the meshing teeth adjacent cutting cones. The skirts being located radially inwardly from the outermost edges of the legs provide passages between the head and the wall of the well. The drawing suggests the presence of a clear solution 35 injected into the well 10 from a pressure conduit 36 which, after flowing through the passages, picks up chips or cuttings 37 and carries them upwardly through the central passage 27. The chip laden fluid then travels upwardly to the ground surface through the drill string to a discharge conduit 38 and is collected in pits (not shown) where the cuttings are separated. It is significant that the central passage 27 is a clear hole above the cutting cones communicating with a hollow interior 28 of the drill string, large enough not to impair the passage upwardly of relatively large chips or cuttings.

A solution suited to the combined drilling and stimulation process is one consisting of calcium chloride wherein the calcium chloride brine is treated with a non ionic or cationic liquified surfactant in proportion of from 1 to 10 parts of surfactant to 1,000 parts brine. The proportion may be adjusted to meet conditions encountered in the bore hole. A density of about 80 pounds per cubic foot has been found acceptable in meeting the condition to which the process is directed, namely, where the producing sand has a heavy burden of clay. The weight of the solution may be advantageously adjusted from 65 pounds per cubic foot, or that just above the weight of formation water, to 88 pounds per cubic foot, or that of the saturation point of a calcium chloride solution. An acceptable surfactant is a nonionic surfactant such as an ethoxylate of an isomeric linear alcohol of which Tergitol 15-S-7 by Union Carbide Corp. is an example.

It is most significant in employment of applicant's method that the solution be a clear solution, namely, one which does not have any appreciable amount of solid particles in it. The clear solution is sent down into the well through the annulus 39 formed between the exterior of the drill string 17 and the casing 11 and then through the annulus formed between the exterior of the drill string 17 and the bore hole wall in the producing formation 13 of the well 10, wherein the fluid is applied under a specific ingoing pressure which is over and above the static pressure which exists to a progressively greater degree at increasing depths. The pressure of 500 to 600 pounds per square inch is variable to some degree, except that in a particular zone, namely, the Ranger Zone in California, this pressure has been found particularly satisfactory. Inasmuch as the pressure is about average between high and low, probably most operations will be found to have good results with application of the method as described within the limits and ranges of the first discussed form of the disclosure. Employment of a greater pressure under circumstances mentioned could cause excess fluid loss into the formations 12, 13 or 14 and perhaps ultimately formation breakdown.

The process is intended for use in the pay zone or oil producing strata only, where the solution of surfactant and calcium chloride brine is allowed to permeate the pay zone in the bore hole area. Since no suspended solids are added to the drilling fluid, and since the circulation of the drilling fluid is in a reverse manner, that is, down the annulus and up through the drill string, there should be little, if any, filter cake formation in the bore hole wall and very little resistance to permeation of the pay zone by the drilling fluid.

The purpose of the surfactant additive is twofold. It serves to lubricate the drilling fluid, thus making it slippery. As such, less energy is required to circulate the drilling fluid in the well, and there is less pump pressure exerted upon the oil producing zone. This is very important since some oil producing zones have relatively low formation pressures, and excessive pump pressure can cause prohibitive amounts of drilling fluid to be lost.
to the pay zone. Furthermore, the slippery, low viscosity drilling fluid greatly reduces pressure surges when running the drill string into the well, which otherwise could cause formation breakdown, or induced fracturing, accompanied by the loss of excessive amounts of drilling fluid. Thus, the intentional permeation of the pay zone by the special drilling fluid is a controlled and uniform intergranular permeation and not channeled or irregular in character.

Also, the surfactant facilitates the exchange of the calcium in the calcium chloride drilling fluid for the sodium in the sodium montmorillonite (bentonite) clays which occupy the intergranular pores, as is true, for example, in most dirty California oil sands. Such an exchange converts the sodium montmorillonite clays, which have a great affinity for water, to calcium montmorillonite clays, which have very little affinity for water, thus expelling water, and dehydrating or collapsing the clay mineral lattice in the process. A decrease in the volume of the intergranular clays, in effect, increases the porosity and permeability of the oil sands in the bore hole vicinity, and thus stimulates the oil sands to produce oil in commercial quantities.

Therefore, many dirty oil sands, which contain millions of barrels of badly needed oil, and do not usually respond to thermal, acid, or hydraulic stimulation processes, can be developed by using the combination drilling and stimulation process herein disclosed. Since the stimulation process actually takes place while drilling is in progress, these oil sands can be stimulated to produce their oil for a fraction of the cost of thermal, acid, or hydraulic stimulation processes, all of which are conducted as separate operations after the drilling operation and at great expense.

Incidental to the employment of a clear solution, as a precaution, the fluid should be circulated down the annulus and up through the drill string for a minute or two before making a pipe connection, namely, addition of a joint of pipe to the drill string as drilling progresses. Employment of this technique helps clear cuttings from the bottom of the drill string and prevents their settling back down inside the drill pipe when the pump is temporarily discontinued. Such a settling would tend to plug the central passage of the bit or cutting cones. A special advantage in employment of the clear solution is elimination of abrasive material such as sand carried by conventional mud.

Using a solution herein defined, sand, which otherwise must be circulated continuously, can be settled out at the surface. Absence of sand or presence of no more than minute quantities of sand is especially helpful in reducing wear on slush pumps, pipe unions, bit bearings and the like. On the contrary, it is almost impossible to exclude a harmful quantity of sand from the conventional water base and oil base drilling muds.

A common practice is the employment of an electric log for determining the characteristics of the penetrated formations. When using a highly conductive drilling fluid, such as the specially prepared calcium chloride solution heretofore discussed, it is advisable to run a focused type of electric log, so that the determinations of electrical resistivity will not be adversely affected by the drilling fluid.

Since the addition of large quantities of a chemical, such as the heavy proportion of calcium chloride, to water produces a solution of ionic concentration greater than that of formation water, a condition is created which prevents the passage of water from the drilling fluid to the formation clay and shale, thus solving many problems associated with the hydration of clay and shale, and consequent production of gumbo, such being heretofore experienced when using water base mud. The character of a solution containing calcium chloride and surfactant is such that they can be readily adjusted to a solution of a higher specific gravity by the addition of an appropriate weight producing soluble chemical, or to a lower specific gravity by the addition of an appropriate amount of water. Though the cost of calcium chloride for the solution is greater than that of water base drilling mud, the solution is such that it can be salvaged and used over again repeatedly. Its cost, moreover, is appreciably lower than that of oil base drilling mud. Avoidance of employment of suspended solids reduces formation damage by minimizing the mudding off of oil zones, and reduces drilling fluid viscosity considerably. A low viscosity drilling fluid reduces pressure losses within the circulating system, reduces the sand content of the circulating fluid, and reduces surge pressures which might cause formation breakdown, with accompanying loss of circulation. Furthermore, the use of a low viscosity drilling fluid, such as specially prepared concentrated solution of calcium chloride, which inhibits the hydration and consequent expansion of clay and shale, reduces the swabbing effect of the drill string when withdrawing it from the bore hole and thereby minimizes a very common cause of blow-outs. A low viscosity drilling fluid can lift relatively large chips up through the drill string, especially when, in making use of the method, the solution travels at three times the speed normally experienced by drilling mud flowing in the conventional pattern.

An additional benefit is experienced in exploration drilling where, by employment of a solution of calcium chloride, oil is more readily and surely detected in the drilling fluid since no oil is added to the solution, in contrast to that of conventional drilling muds. Evidence of oil encountered in formations on the way down can be much more readily detected in the character of the chips and the chip laden solution emerging at the surface. To put this in terms of the trade, oil may occur in virtually any type of reservoir from thin-bedded sands to fractured shale and defy detection by the electric log. Oil shows of higher fractions can become emulsified in drilling muds and defy detection by mud loggers. Use of a clear drilling fluid such as that herein recommended, and returning to the surface up through the drill pipe at a rate of 450 feet per minute carrying cuttings three to four times the size normally expected makes possible a more conclusive evaluation of the formations penetrated.

Having described the invention, what is claimed as new in support of Letters Patent is:

1. A combination drilling and stimulation process for oil wells making use of a hollow drill string and drill head having individual rotary cone bits thereon comprising:

- forming a clear discharge passage from a space intermediate the cone bits through the drill head to the drill string,
extending said drill head into earth strata to form a well section and providing an annular stimulation passage between the exterior of the drill string and the wall of the well throughout the oil producing strata,

preparing a clear solution having a weight in pounds per cubic foot greater than that of the formation water, said solution comprising water and a mixture of calcium chloride and a surfactant wherein the surfactant is in proportion of about 1 to 10 parts per 1,000 parts calcium chloride solution to serve as a drilling solution,

forcing said solution under pump pressure downwardly around the exterior of the drill string, forcing a portion of said solution from the annular stimulation passage into the oil producing strata while drilling progresses, continuing to force another portion of the solution toward the bottom of the well section, and from the bottom of the well section through said clear discharge passage and past said cone bits, using the solution to pick up chips of said strata generated by operation of the cone bits and forcing said solution and accompanying chips under a combination of pump and static pressure up through the drill string,

removing solids including sand and said chips from the solution at the surface until said solution is substantially clear and recirculating said solution from which solids have been cleared by again forcing it down said annular passage.

2. The method of drilling oil wells as in claim 1 including preparing the solution with a weight of between 65 and 120 pounds per cubic foot.

3. The method of drilling oil wells as in claim 1 wherein the ionic content of the solution is made greater than the ionic concentration of formation water encountered in the well.

4. A method of drilling oil wells as in claim 1 wherein the pump pressure at which the solution is forced into the annular passage is between about 500 and 600 pounds per square inch.

5. A method of drilling oil wells as in claim 1 wherein the surfactant is nonionic and comprises an ethoxylate of an isomeric linear alcohol.

6. A method of drilling oil wells as in claim 5 wherein the weight of the solution is between 65 and 88 pounds per cubic foot.

7. A method of drilling oil wells as in claim 5 wherein the weight of the solution is about 80 pounds per cubic foot.

8. A method of drilling oil wells as in claim 5 wherein the solution has an A.P.I. funnel viscosity of about 32 seconds per 1,000 cubic centimeters.

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